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DIMENSIONS OF TWIN SEAPLANE FLOATS

By L. Meyer

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The designing of a seaplane float is a difficult task which is often successfully accomplished only after repeated trials. It is seldom that the floats used in the first tests are retained without important modifications. Recently six pairs of floats were tried successively on the same seaplane before arriving at the final form. Without admitting a prodigious lack of skill on the part of the engineers or a pusillanimous spirit of criticism on the part of the pilots, we must recognize the lack of precise data for making the designs. Nevertheless, during recent years, excellent floats have been made and have received a sort of consecration from the Test Committee of Saint Raphael. The designers naturally seek for inspiration in their new researches, but they encounter one difficulty. They do not know the laws governing the variation in the dimensions involved, such as the length and width; or rather there is no general agreement, which amounts to the same thing. The object of the present article is to discover these laws by disregarding theoretical considerations and taking as their basis the reports of the test committee.

In the design of a float there are two kinds of elements: first, the principal dimensions of the volume, length, width, and height of the maximum section; and second, the shape of the bottom from stem to stern, the shape of the deck, the location of the step, the inclination of the keel in front of and in back of the step, etc. Neither of these two categories is less important than the other, but we shall here occupy ourselves chiefly with the elements of the first category, those of the second category being considered only from the viewpoint of their repercussion on the former. We propose:

1. To establish a condition of the floats presented to the Test Committee of Saint Raphael in recent years;

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*"Les dimensions des flotteurs d'hydravion en catamaran. Association Technique Maritime et Aéronautique, May 1933.

2. To seek, for all the floats found good, the laws which best express the variation of the principal dimensions in terms of the tonnage (length and volume of float; width, height and area of maximum section);

3. To verify the mutual agreement of the five laws thus found;

4. To apply these laws to each float tested, good or bad, in such manner as to determine whether the principal dimensions with respect to these laws accord with the observations made by the test committee;

5. To determine the range of the formulas found.

Characteristics of the Floats Presented to the Test Committee

These are shown in table I. Each seaplane is designated by a capital letter, while the floats are distinguished by small letters. Each seaplane is characterized briefly by the following data:

P, weight in metric tons, this being the gross weight at which the tests were made;

W, horsepower, the figure given being that of the power equivalent;

S, wing area, in square meters;

$\frac{P}{S} \times 1{,}000$, wing loading in kg/m²;

$\frac{P}{W} \times 1{,}000$, power loading in kg/hp;

For each float we give:

L, length in meters;

s, maximum section in square meters;

l, " width " meters;

h, " height " " ;

V, volume in cubic meters;

α, angle characterizing the damping at the step. It is the angle with the horizontal made by the straight line joining the central keel to the chine.

In the exceptional case where s, l, and h are not the maximums at the step, the figure used is the mean between the maximum and the figure at the step.

The floats are those presented from 1926 to 1933. We have omitted some, either because we could not obtain their exact characteristics or because they differed from the floats enumerated here only by characteristics other than those which form the subjects of the present investigation (longitudinal setting, location of step, rise of the after keel, etc.), or, lastly, because they constituted only an intermediate stage of no interest in itself. Excepting these intentional omissions, table I includes all the twin floats on which the Saint Raphael committee passed judgment during this period.

Relations between the Principal Dimensions and the Tonnage

We seek, for each of the principal dimensions, the function which best expresses its variation in terms of the tonnage of the seaplane. More exactly, commencing, for example, with the over-all length L, we seek the values of K and n such that

$$P = KL^n \tag{1}$$

best expresses the correlative variation of the length L of the float and of the tonnage P of the seaplane. We first eliminate those floats from the table, the length of which has afforded ground for criticism, or for any reason, has not been retained, namely the floats C, Ea, Ia, Ka, La, Ma, Oa, Sa.

Each of the other floats yields, on replacing P and L by their respective values in formula 1, a relationship between n and K. On passing to the logarithms, this relationship assumes a linear form

$$\log P = \log K + n \log L \tag{2}$$

which yields a straight line in a system of axes having the coordinates n and $\log K$. Each float thus yields a straight line. If these lines were concurrent, the coordinates of their point of concurrence would yield values of K and n which would make it possible to express exactly by formula 1 the correlative variation of L and P. In fact, the lines are not concurrent, but are clearly convergent, with two exceptions (corresponding to the floats F and Y). Disregarding these two lines, we adopt, as the values of $\log K$ and of n, the coordinates of the point about which the bundle of lines gather (fig. 1):

$$\log K = -1.91$$
$$n = 2.7$$

Between L and P we thus have the relation

$$P = 0.0123\ L^{2.7}$$
$$\text{or}\quad L = 5.1\ P^{0.37} \tag{3}$$

formulas in which P is expressed in metric tons and L in meters.

Let us apply this method successively to the maximum sections s, the length l, the height h, and the volume V. For the maximum section we first eliminate the floats La, Ma, and Oa. With the other floats we obtain figure 2. Disregarding three lines corresponding to the floats B, K, and N, we find

$$\log K = 0.74$$
$$n = 1.2$$

which yield the relation between s and P

$$P = 5.5\ s^{1.2}$$
$$\text{or}\quad s = 0.24\ P^{0.83} \tag{4}$$

In these formulas P is expressed in metric tons and s in square meters.

For the width we first eliminate the floats La, Ma, and Oa. With the other floats we obtain figure 3. Disregarding two lines corresponding to the floats C and N, we find

$$\log K = 0.42$$
$$n = 2$$

which yield, between l and P, the relation

$$P = 2.6\ l^2$$
$$\text{or} \quad l = 0.62\sqrt{P} \qquad (5)$$

In these formulas P is expressed in metric tons and l in meters.

For the height, we eliminate the floats La, Ma, and Oa, as before, and obtain figure 4 with the others. Disregarding a straight line corresponding to the float Ob, we find, as the coordinates of the center of the bundle,

$$\log K = 0.9$$
$$n = 3$$

which yield, between h and P, the relation

$$P = 8\ h^3$$
$$\text{or} \quad h = 0.5\ P^{0.33} \qquad (6)$$

P being expressed in metric tons and h in meters.

Lastly, for the volume, we eliminate the floats Ea, Ka, La, Ma, Oa, and Sa, and obtain figure 5 with the others. Disregarding four lines corresponding to the floats B, N, Y, and Kb, we find, as coordinates of the center of the bundle,

$$\log K = 0.07$$
$$n = 0.83$$

which yield, between V and P, the relation

$$P = 1.18\ V^{0.83}$$
$$\text{or} \quad V = 0.82\ P^{1.2} \qquad (7)$$

P being expressed in metric tons and V in cubic meters.

<u>Mutual accord of the preceding relations</u>.- We have thus found five relations:

$$L = 5.1\ P^{0.37}$$
$$s = 0.24\ P^{0.83}$$

$$l = 0.62\ P^{0.3}$$
$$h = 0.5\ \ P^{0.33}$$
$$V = 0.82\ P^{1.3}$$

On combining them we immediately obtain

$$\frac{V}{L\ s} = \text{constant} = \frac{0.82}{5.1 \times 0.24} = 0.67$$

$$\frac{V}{L\ l\ h} = \text{constant} = \frac{0.82}{5.1 \times 0.62 \times 0.5} = 0.52$$

$$\frac{s}{l\ h} = \text{constant} = \frac{0.24}{0.6 \times 0.5} = 0.77$$

On the other hand, we calculated for each float the values of the expressions

$\frac{V}{L\ s}$, $\frac{V}{L\ l\ h}$, $\frac{s}{l\ h}$ (See first three columns of table II.)

We thus find that:

V/Ls is comprised between 0.64 and 0.72 (excluding float F); mean value, 0.68.
V/Llh is comprised between 0.46 and 0.58 (excluding floats F, N, and Ob); mean value, 0.52.
s/lh is comprised between 0.67 and 0.82 (excluding floats N, Ob, and Oc); mean value, 0.75.

There is accord therefore between the five relations found, both for the exponents of P and for the coefficients. The formulas verify one another.

Comparison of Test Results with Laws Found

We discovered the above laws by finding the coordinates of the point of approximate convergence of a bundle of straight lines. These laws are only approximate. It is now well to determine in what degree each of the quantities investigated can differ from the corresponding mean law, while being represented by one of the convergent lines. Practically, for each quantity, we will consider the exponent of P constant and we will endeavor to discover the limits of the ratios

$$\frac{L}{P^{0.37}}, \frac{s}{P^{0.83}}, \frac{l}{P^{0.5}}, \frac{h}{P^{0.33}}, \frac{V}{P^{1.2}}$$

for all the floats represented in the corresponding bundle.

The values of these ratios are given in table II, and it is immediately obvious that:

for	L,	the ratio	varies	between	4.930	and	5.250;
"	s,	"	"	"	0.218	"	0.262;
"	l,	"	"	"	0.586	"	0.662;
"	h,	"	"	"	0.452	"	0.558;
"	V,	"	"	"	0.770	"	0.902.

We have thus established, for each quantity, the zone of the normal values on both sides of the mean low. We will now be able to show, for each float in the table, the position of its coefficients with respect to normal limits and the observations made during the tests, in such manner as to determine whether there is a correlation between the passing of these limits and the experimental phenomena.

Unless otherwise indicated, all the floats underwent complete tests on both calm and rough water and by different pilots.

We will at first disregard the floats,

A, D, Eb, H, Ib, Oc, P, R, Sb, T, V, X, Z

whose coefficients are within normal limits and which are recognized as well adapted, and review the floats which present peculiarities.

Float B.- Criticisms by the committee: inadequate damping; poorly distributed volume (insufficient volume forward); insufficient rise of the after part of the keel.

Value of the coefficients: length, width, and height within the limits; excessive volume and maximum section.

It is obvious that by raising the keelsons in the medium part, while lowering the central keel forward, one would remedy the defects mentioned while restoring the volume and maximum section to within the limits. These improvements were not attempted, and the design was abandoned.

<u>Float C</u>.- Criticisms by the committee: too long; ratio of length to width exceptionally great; volume excessive; tendency to stall in taking off.

Value of the coefficients: length above the limits; width below the limits; volume at the upper limit; other coefficients within the limits.

Remedying these defects, which was not attempted, would normally have involved a reduction in the length and a retrogression of the step, which would have brought all the coefficients, except that of width, within the limits.

<u>Float Ea</u>.- This is the same float as D, but the weight of the seaplane was increased.

Criticisms by the committee: inadequate volume and length (stern submerged too much).

Value of the coefficients: volume and length below the limits; the other quantities within the limits.

<u>Float F</u>.- The tests were prematurely abandoned due to defects of the seaplane. Till then the dimensions of the float were considered good. All the coefficients are within the limits, excepting that of length which is excessive.

The float has a very peculiar shape, as shown by the exceptional values of the ratios

$$\frac{V}{L\ s} \text{ and } \frac{V}{L\ l\ h}.$$

<u>Float Ia</u>.- This is derived from the float B. The designer effected a transformation by similitude by taking

$$\frac{L}{L'} = \frac{l}{l'} = \frac{h}{h'} = \left(\frac{P}{P'}\right)^{\frac{1}{2 \cdot 3}}$$

and by starting with a weight of 6,800 kg for the seaplane with the floats B.

The float thus obtained is less satisfactory than the float R. with 6,800 kg. The longitudinal setting became more difficult and the float had to be advanced in order to improve the take-off. Thus advanced, the float is acceptable, excepting that the shape of the stern impedes the take-off. This was remedied by changing the design of the stern which entailed a lengthening of the float. The float Ib thus obtained was satisfactory.

Value of the coefficients: Ia was at the lower limit for the length and within the limits for the other dimensions. Ib is within the limits for all the dimensions.

Floats Ka and Kb.- Float Ka was bad; it lacked in both volume and length. The designer lengthened it by 0.95 m, increasing the volume at the same time. This was a decided improvement, but the float Kb thus obtained is still only mediocre.

Value of the coefficients: for Ka, the volume, maximum section and length are below the limits; for Kb, the length is within the limits, but the maximum section and the volume are still below.

Float La.- This was derived from the float Kb. Although the seaplane weighs less, the designer tried to improve the float by making it still longer.

Criticisms by the committee: float too slender; despite its length, its volume is inadequate in front; quite severe shocks.

Value of the coefficients: length beyond the limits; maximum section below; the others within.

After several intermediate stages, a new float Lb was obtained.

Float Lb.- Differs from the preceding by a reduction in length, an increase in width and height and in the damping. The result is considered satisfactory, though the shocks are still rather severe. The load of the seaplane was slightly increased.

The coefficients are all within the limits.

Floats Ma and Mb.- The float Ma was bad. The water splashes were so great that the tests had to be discontinued.

This result being attributed to an inadequancy of volume, the designer increased all the dimensions in the same proportion. The tests with the new float Mb were interrupted prematurely by an accident in landing on rough water.

Value of the coefficients: for Ma, all were below the limits save the coefficient of width; for Mb, all the coefficients are within the limits.

Float N.- Considered very good.

The coefficients of width, of the maximum section and of volume are above the limits; the length and height are within the limits.

The seaplane was a very old one. The small wing loading explains why the flat bottom and great width did not cause trouble. The excess of the maximum section and of volume were due to the peculiar, almost rectangular shape of the section ($s/lh = 0.946$), which has now been abandoned.

Float Oa.- This is the same as the float N, but the seaplane is more powerful and heavy.

Criticisms by the committee: shocks too heavy; longitudinal oscillations; the seaplane does not rise with the waves; the bow is submerged too much in normal flotation.

Value of the coefficients: the coefficients of length and height are below the lower limits; the other coefficients are normal; the increase in wing loading explains why the flat bottom does not give better satisfaction.

A new float Ob was designed.

Float Ob.- Observations by the committee: good proportions, but excessive shocks.

Value of the coefficients: the coefficients are within the limits, except the coefficient of height.

The damping was increased by lowering the central keel, the shocks were remedied and the coefficient of height was brought within the limits. The float Oc, which has been found satisfactory, was thus obtained. The carrying capacity of the seaplane was also increased.

Float Sa.- Criticisms of the committee: does not rise with the waves (insufficient volume forward).

Value of the coefficients: the coefficients were within the limits, excepting the coefficients of length and volume which were below the lower limit.

The float was lengthened in order to remedy these defects. Thus Sb was obtained, all of whose coefficients are within the normal limits and which is considered very satisfactory.

Float Y.- This has undergone only brief tests in still water. It seems to be well designed. Its coefficients of length and volume are below the limit.

It is the only case we have met where the inadequacy of these coefficients is not accompanied by criticisms on the part of the committee. This fact is explained by the briefness of the tests and especially by the absence of tests on rough water.

This detailed examination shows that experimental phenomena attributable to the dimensions of the floats always have, as a counterpart, a value of the coefficient outside the limits found. This is a very remarkable coincidence.

On the other hand, we find that the fact for certain coefficients outside the limiting values does not necessarily involve any experimental defect. We will return to this point, which merits further investigation.

In accord with the various observations made on the floats investigated, we can now define as follows the normal limits of the different dimensions:

$L =$	4.95	to	$5.25\ P^{0.37}$	or	$5.1\ P^{0.37}$	± 3 percent
$s =$	0.22	"	$0.26\ P^{0.83}$	"	$0.24\ P^{0.83}$	± 8 "
$l =$	0.58	"	$0.66\ P^{0.5}$	"	$0.62\ P^{0.5}$	± 6.5 "
$h =$	0.45	"	$0.55\ P^{0.33}$	"	$0.5\ P^{0.33}$	± 10 "
$V =$	0.76	"	$0.88\ P^{1.2}$	"	$0.82\ P^{1.2}$	± 7.5 "

in which formulas, we have:

P expressed in metric tons;

L, l, h, expressed in meters;

s expressed in square meters;

V " " cubic meters.

Discussion of the Formulas

These formulas show an evolution of the floats in terms of the tonnage. As the weight increases, the mean section is more flattened. This is quite remarkable, because it is at variance with statements often made by British and American writers (reference 1). According to them, each dimension of the float varies almost as the cube root of the weight, and some go so far as to say that, by starting with a satisfactory float and applying this simple law, one can derive floats for seaplanes of different tonnage. They take care to add, however, that this is only a first approximation which should be first verified by a tank test. Nevertheless, we have never seen any account of successful floats derived from others by this process and for substantially different tonnages. Pending proof to the contrary, we shall not consider this simplification as technically correct.

There is probably an element of truth, however, in the tendency thus affirmed. Insofar as the foreign floats are known to us, it seems in fact that their width tends to increase less rapidly than the width of our floats, though their length and height are of the same order. Consequently their volume is less for large tonnages and the "deformation" of the mean section is less pronounced. This is doubtless the explanation of the above-mentioned proposition. The step is placed farther forward on these floats than on ours, which compensates for their smaller width. The process of taking off must be a little different.

We cannot say as to which of these two methods is the better, because the necessary data can be supplied only by tests conducted according to a strict method of comparison. We have not yet tested narrow floats at Saint Raphael. Our table contains only one float (C) with this tendency, but its unusual length affects the conditions and makes it impossible to draw definite conclusions.

We dwell on this point, because it makes it necessary for us to define the range of our formulas. These formulas are to be considered as representing the tests executed at Saint Raphael in recent years. They furnish a simple expression for the dimensions of satisfactory floats, and they also take account of the recorded failures. They can therefore probably be utilized for designing new floats. Theydo not, however, represent systematically conducted tests in which one would be forced to determine for each case the best float by a variation of the different elements. In fact the object sought each time was to obtain a float permitting the utilization of the seaplane. After this object had been attained, no new tests were made, if there were other acceptable solutions. It is not surprising therefore that certain solutions, such as we have indicated, can exist outside of our formulas.

On one point, however, the Saint Raphael tests showed quite a definte limit, beyond which it seems imprudent to venture, namely the lower limit of length. We are aware of the fact that it may seem a little summary thus to consider a single dimension by itself, independently of the other elements of the form of the float. Nevertheless we have encountered successively six floats which, having originally a coefficient of length below the limit, had to be lengthened or replaced by longer floats and in each case, after regaining the limit, the defect was no longer conspicuous. On the other hand a single float (Y) having a coefficient of length below this limit was not criticised, but it must be remembered that it had not been really tested.

The length was intentionally made the object of a more accurate determination than the other dimensions. There are two reasons for this. The first is that inadequacy of length is manifested by disagreeable phenomena which are easily observed. The seaplane does not rise properly on the waves; it plunges and projects much spray, and pitches violently, particularly just after landing. The second reason is that the remedy is comparatively simple, it being much easier to increase the length of a float, rather than its width or height.

As regards the length, the narrowness of the zone between the two limits should be noted. The upper limit is not, however, of the same character as the lower limit. Excess length does not entail such serious consequences as insufficient length. Up to a certain point and when the wing loading is small (the case of the float F and of every seaplane taking off with a light load), an excess of length would not seem to have any disadvantages on the water. It is simply to be rejected as useless; it being possible to utilize the weight better for other purposes. In fact designers tend to exceed the lower limit as little as possible.

Moreover, excessive length has its dangers, beyond a certain limit, One is exposed, for example, to excessive pitching in taking off, causing a premature take-off with stalling (case of float C); or the shocks in front have greater repercussions (float La); or the shape of the front ends disturbs the maneuvers. Furthermore, if the other dimensions are not according to scale, the stresses in the float will be greater, and, since the designer will be tempted to lighten the structure in order to keep within the normal weight limits, the float will be weakened. In fact the floats C, F, and La exhibit such weakness.

It should not be surprising that our formulas determine the height only within rather broad limits, because this is affected by the diversity of shapes of the mean sections (damping of the bottom and a more or less rounding of the top). As to the width, we have already explained how the lower limit is to be determined. The floats tested do not make it possible to determine with certainty the disadvantages entailed by exceeding the upper limit. However, all the floats whose coefficients of width approach or exceed this limit, belong to seaplanes of small wing loading (floats A, H, N, Ob, Oc), except the float Mb whose tests were prematurely interrupted by the failure of the landing gear in taking off from rough water, and the float Lb which was subject to excessive shocks. We are therefore led to conclude that great widths are compatible only with small values of P/S (i.e., with low take-off and landing speeds), while, of course, being capable of correction to some extent by the damping of the forms.

There is another question presented by our formulas. It is quite remarkable that the dimensions of floats can be kept within such narrow limits without introducing into the formulas any variable other than the weight. An examination of table I shows, however, that it deals with seaplanes of quite varied characteristics. The power loadings range from 4 to 8 kg/hp; the wing loadings, from 30 to

86 kg/m^2; and the outlines and general dispositions are no less varied. In our opinion this is not a sufficient reason for concluding that P/S and P/W have no influence. On the contrary, we have just called attention to the effect of the wing loading on the upper limits of the length and width. As we have said, our formulas represent only the "optimum" floats, and it is probable that formulas defining the optimum float for each case would be a little more complex.

In order to obtain an idea of the influence exerted by the variations of P/S and P/W, it is quite natural to consider the extreme conditions represented by the floats or racing seaplanes. We have not mentioned them thus far, because, on the one hand, we were limiting ourselves voluntarily to the floats investigated by the Saint Raphael Committee and because, on the other hand, very little is required of racing seaplanes as regards seagoing qualities. Nevertheless it may be of interest to see what becomes of our coefficients in this particular case. Table III contains some figures regarding the three Supermarine seaplanes which won the Schneider Cup in 1927, 1929, and 1931. Some interesting conclusions can be drawn from these figures. The width closely follows the law of the cube root, with a correction tending to reduce the length slightly in proportion to the progression of the wing loading. The height is very great, which is easily explained by the greatness of the damping and by the aerodynamically well-designed top. The length is remarkably small on the S 6, but it must not be forgotten that for these seaplanes the requirements regarding the spray, riding the waves, and pitching are not nearly so severe as for the seaplanes investigated, and that the impression of witnesses of the three flights was that the S 6 had marine qualities appreciably inferior to its predecessor and successor. Lastly, it is interesting to note that the very high power in proportion to the weight and to the wing area does not require any great aspect ratio of the float to correct the diving moment in taking off.

We can now specify the uses which may be made of the formulas given and the values to be assigned to the limits indicated by them.

1. It is certainly possible, by following these formulas, to design satisfactory floats for seaplanes of normal wing loading, i.e., between 35 and 85 kg/m^2.

2. The lower limit of L must be strictly observed for a float which is to possess good seaworthiness. The upper limit is imperative only for seaplanes with a heavy wing loading (say above 70 kg/m^2), but there would never appear to be any advantage in exceeding it.

3. The lower limit indicated for l is simply characteristic of the floats tested at Saint Raphaël and actually in service. Nothing obliges us to regard it as imperative. Probably the true lower limit is expressed by a function of P with a smaller exponent. The upper limit is imperative for heavily loaded seaplanes and even for these it should doubtless be lowered. For seaplanes with a wing loading of less than 50 kg/m^2, it may simply be said that there is no advantage in exceeding it. It appears that, for seaplanes whose wing loading would increase from 35 to 85 kg/m^2, the width of the float might be simultaneously reduced from the upper to the lower limit.*

4. The lower limit of h can be considered imperative, and there would appear to be no advantage in exceeding the upper limit. Between these two limits, the more rapidly the height of the section diminishes on both sides of the axis of symmetry, the more advantageous it is to approach the upper limit.

5. If the limits are observed for L, l, and h, and if the detail drawing is well done, one should arrive at the values of s and V comprised within the limits given for these elements, because the values of the ratios V/Ls, V/Llh, and s/lh should not differ much from the mean figures that have been indicated. There is no advantage in exceeding the upper limits, and, on the other hand, for floats of the narrowest type, the lower limit of s and of V should be expressed by a function of P with a smaller exponent.

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*It is well to note that, strictly speaking, the characteristic involved is not P/S, but the take-off speed, and that it is necessary, rather, to consider the ratio $P/C_z S$, in which C_z representes the coefficient of maximum lift of the airfoil. Thus the seaplane F, the profile C_z of which increases to 1.4, is not really more heavily loaded than the seaplane N whose profile C_z does not exceed unity.

REFERENCE

1. Richardson, Holden C.: Aircraft Float Design. The Ronald Press Company, New York, 1928.

Munro: Factors in Seaplane Float Design. The Aircraft Engineer, July 19, 1928.

Parkinson: Notes on the Design of Twin Seaplane Floats. The Aircraft Engineer, Feb. 23, 1933.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

Designation	P t	W hp	S m^2	$\frac{P}{W}$ x 1000	$\frac{P}{S}$ x 1000	L m	s m^2	ℓ m	h m	V m^3	α
A	1,480	300	29,5	4,93	50,2	6,02	0,335	0,794	0,562	1,85	12
B	2,225	500	47	4,45	47,3	6,87	0,54	0,94	0,70	2,6	5
C	2,450	465	50	5,27	49	8,00	0,465	0,82	0,726	2,6	11
D	2,310	405	40	5,7	57,7	6,85	0,49	0,92	0,689	2,2	12
Ea	2,460	500	41	4,92	60	d°	d°	d°	d°	d°	d°
Eb	d°	d°	d°	d°	d°	7,22	d°	d°	d°	2,35	d°
F	2,530	450	66	5,62	38,3	8,30	0,56	0,95	0,76	2,6	16
H	2,850	490	58,5	5,81	48,7	7,27	0,62	1,10	0,78	3,05	18
Ia	4,200	620	76	6,77	55,2	8,40	0,77	1,30	0,745	4,6	13
Ib	d°	d°	d°	d°	d°	8,87	d°	d°	d°	d°	d°
Ka	5,020	620	58	8,1	86,5	8,40	0,78	1,35	0,825	4,52	13
Kb	d°	d°	d°	d°	d°	9,35	d°	d°	d°	4,82	d°
La	4,650	720	58	6,45	80,2	9,59	0,76	1,35	0,823	5,15	12
Lb	4,800	d°	d°	6,66	82,7	9,37	0,87	1,45	0,89	5,91	16
Ma	4,930	750	71	6,57	69,5	8,10	0,80	1,32	0,75	4,49	15
Mb	5,070	d°	d°	6,76	71,5	9,00	0,98	1,465	0,832	6,30	d°
N	4,800	600	161	8,0	29,8	9,30	1,13	1,50	0,795	7,20	0
Oa	5,830	810	153	7,2	38,1	d°	d°	d°	d°	d°	d°
Ob	5,930	d°	d°	7,32	38,8	9,75	1,11	1,605	0,75	7,20	3,5
Oc	6,200	d°	d°	7,65	40,5	9,82	1,19	1,645	0,83	7,50	11
P	6,200	810	166	7,65	39,7	10,20	1,04	1,51	0,915	7,40	13
R	7,000	990	159	7,06	44	10,20	1,14	1,60	0,918	8,30	15
Sa	6,800	1120	120	6,06	56,6	9,75	1,10	1,55	1,00	7,65	19
Sb	d°	d°	d°	d°	d°	10,15	d°	d°	d°	7,74	d°
T	7,200	1120	120	6,42	60	10,40	1,20	1,577	1,03	8,25	19
V	6,800	1520	119	4,47	57,1	d°	d°	d°	d°	d°	d°
X	7,670	1440	139	5,32	55,2	10,87	1,29	1,648	1,04	9,54	18
Y	7,660	990	117	7,73	65,3	10,00	1,18	1,615	0,99	8,40	20
Z	7,460	990	123	7,62	60,5	11,00	1,37	1,735	1,00	10,00	9

m x 3.28083 = ft. t x 2204.62 = lb.
m^2 x 10.7639 = sq.ft. kg/m^2 x .204818 = lb./sq.ft.
m^3 x 35.3145 = cu.ft. kg/hp x 2.17442 = lb./hp

Table I

Designation	$\frac{V}{L \times s}$	$\frac{V}{L \times l \times h}$	$\frac{s}{l \times h}$	$\frac{L}{P^{0.37}}$	$\frac{s}{P^{0.483}}$	$\frac{l}{P^{0.5}}$	$\frac{h}{P^{0.33}}$	$\frac{V}{P^{1.2}}$
A	0,67	0,502	0,75	5,19	0,242	0,656	0,495	0,844
B	0,7	0,575	0,82	5,1	0,278	0,631	0,536	0,996
C	0,7	0,546	0,782	5,73	0,221	0,522	0,539	0,887
D	0,656	0,506	0,774	5,02	0,25	0,605	0,522	0,803
Ea	d°	d°	d°	4,89	0,237	0,586	0,511	0,745
Eb	0,664	0,513	d°	5,16	d°	d°	d°	0,796
F	0,56	0,434	0,775	5,88	0,259	0,597	0,558	0,85
H	0,677	0,49	0,722	4,95	0,259	0,65	0,551	0,867
Ia	0,711	0,565	0,795	4,93	0,234	0,834	0,462	0,822
Ib	0,673	0,535	d°	5,22	d°	d°	d°	d°
Ka	0,69	0,484	0,7	4,62	0,204	0,602	0,482	0,654
Kb	0,662	0,463	d°	5,15	d°	d°	d°	0,697
La	0,706	0,483	0,684	5,43	0,212	0,625	0,493	0,814
Lb	0,724	0,488	0,674	5,25	0,237	0,662	0,528	0,902
Ma	0,692	0,56	0,808	4,47	0,213	0,595	0,442	0,661
Mb	0,714	0,574	0,804	4,93	0,254	0,65	0,485	0,897
N	0,685	0,65	0,946	5,21	0,308	0,685	0,472	1,1
Oa	d°	d°	d°	4,83	0,261	0,621	0,442	0,865
Ob	0,665	0,613	0,922	5,05	0,252	0,658	0,414	0,851
Oc	0,641	0,559	0,871	4,98	0,262	0,661	0,452	0,84
P	0,697	0,525	0,752	5,17	0,234	0,606	0,499	0,83
R	0,714	0,554	0,776	4,97	0,226	0,603	0,481	0,803
Sa	0,713	0,506	0,71	4,8	0,224	0,594	0,528	0,765
Sb	0,693	0,492	d°	5,0	d°	d°	d°	0,774
T	0,661	0,488	0,738	5,02	0,234	0,587	0,534	0,77
V	d°	d°	d°	5,12	0,244	0,604	0,544	0,825
X	0,680	0,511	0,752	5,1	0,238	0,594	0,528	0,825
Y	0,71	0,525	0,737	4,72	0,218	0,589	0,503	0,73
Z	0,664	0,524	0,789	5,23	0,258	0,636	0,512	0,9

Table II

	P t	W hp	S m²	$\frac{P}{W} \times 1000$	$\frac{P}{S} \times 1000$	L m	l m	h m	α	$\frac{L}{P^{0.37}}$	$\frac{l}{\sqrt{P}}$	$\frac{l}{\sqrt[3]{P}}$	$\frac{h}{\sqrt[3]{P}}$
S.5	1475	900	10,7	1,64	138	5,63	0,676	0,675	30	4,88	0,557	0,595	0,594
S.6	2380	1900	13,5	1,25	176	5,86	0,78	0,80	30	4,24	0,506	0,585	0,60
S.6 B	2720	2300	13,5	1,18	201	7,20	0,80	0,80	25	4,96	0,485	0,574	0,574

Table III

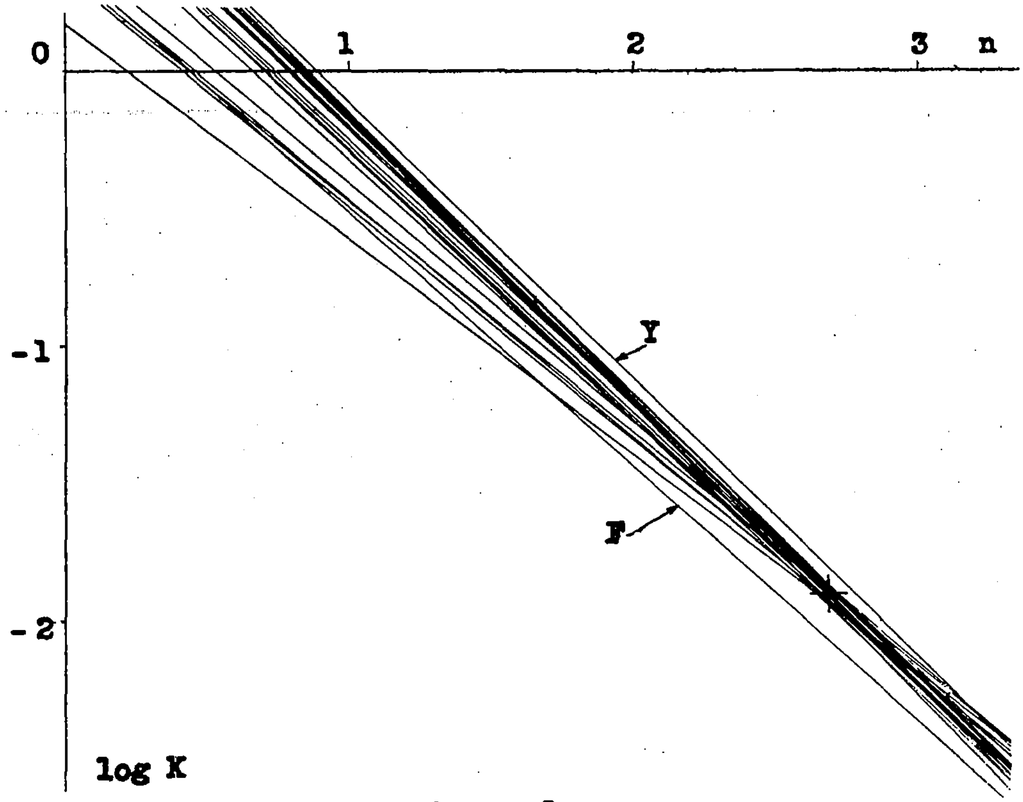

Figure 1.

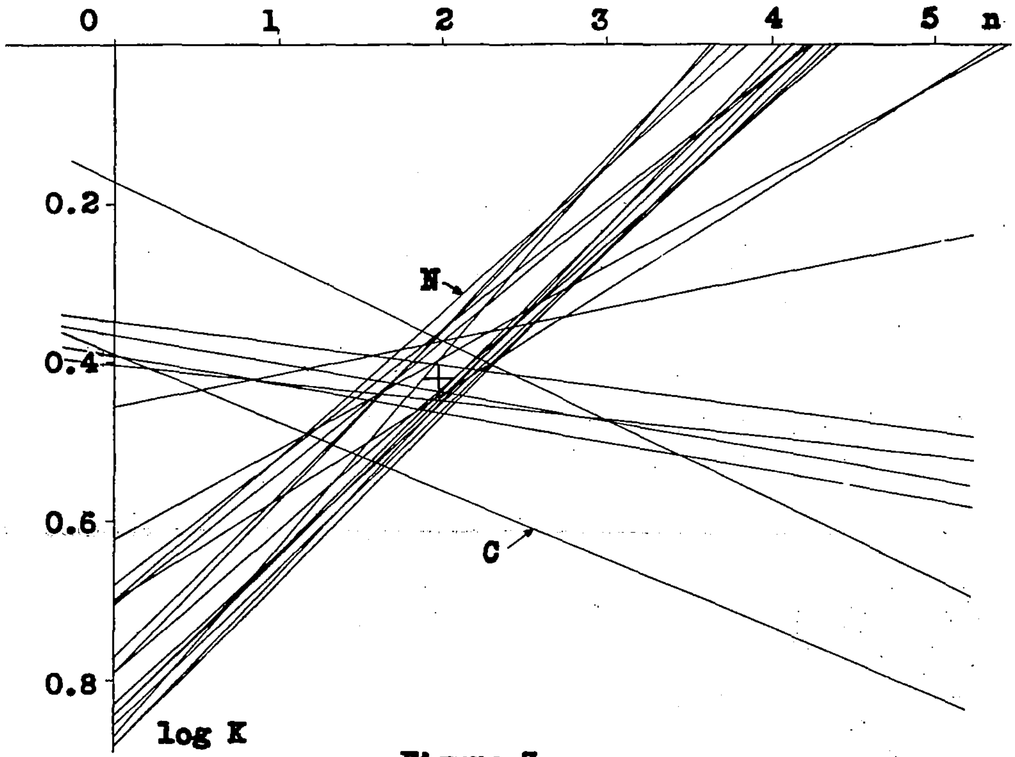

Figure 3.

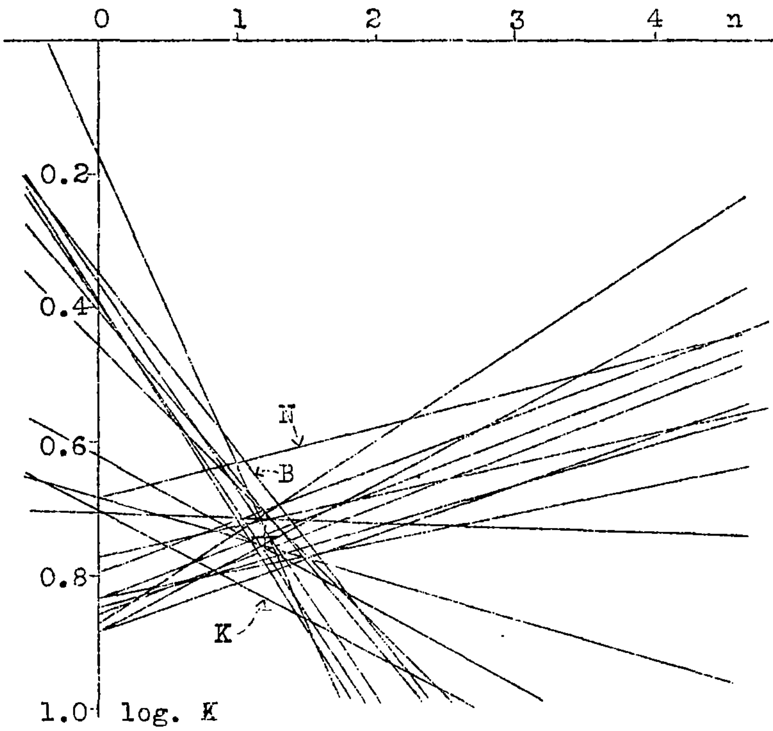

Figure 2.

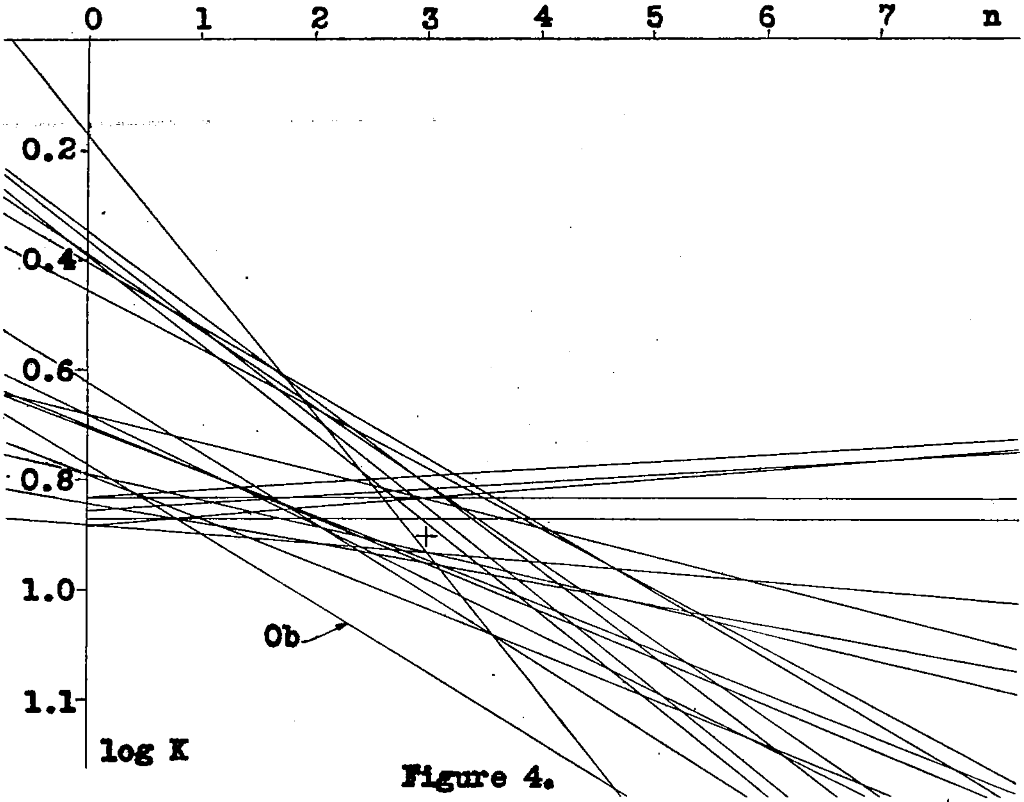

Figure 4.

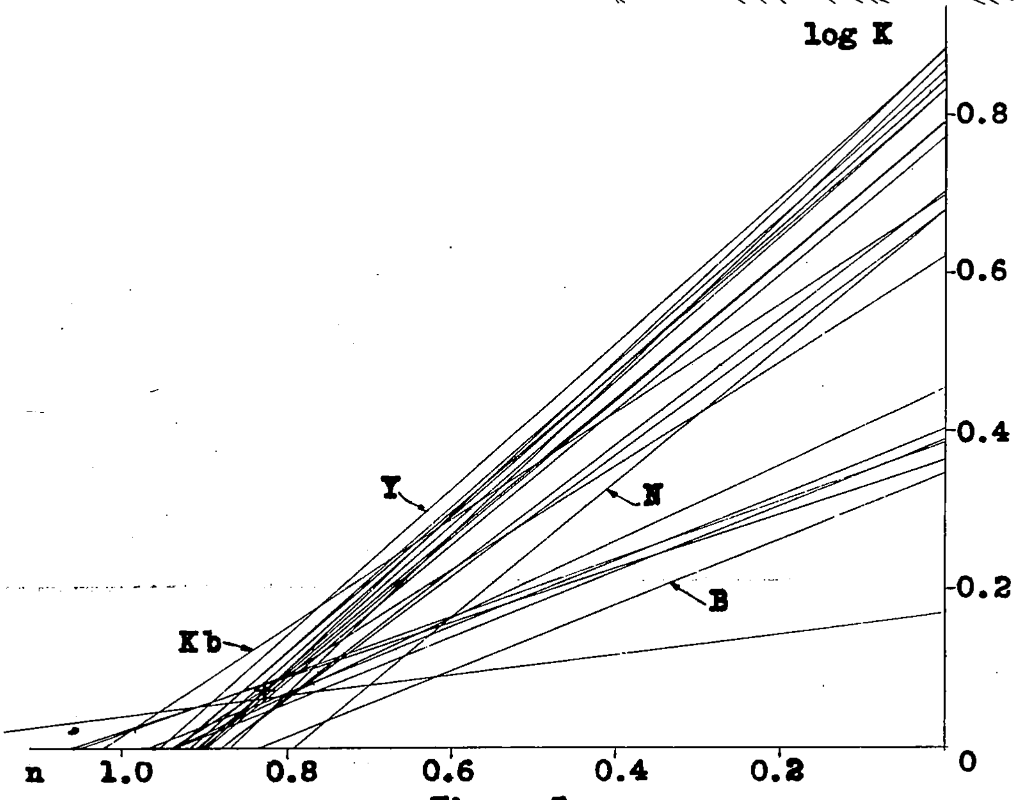

Figure 5.